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Environmental Research Lab.-Duluth, Minnesota

1977

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Made in the United States of America
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Vol. 106, No. 4, July 1977
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EPA-600/J-77-052
JOURNAL ARTICLE

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Spawning Success of the Black Crappie, *Pomoxis nigromaculatus*, at Reduced Dissolved Oxygen Concentrations

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ABSTRACT

Mature black crappies (*Pomoxis nigromaculatus*) were exposed to constant dissolved oxygen (DO) concentrations near or at 2.5, 3.5, 5.0, or 6.5 mg/liter, and near air saturation (control) to determine the effects of reduced DO on spawning success. The fish spawned successfully 39 times in laboratory tanks under a simulated natural temperature and light regime at all DO concentrations tested. Fish at 2.5 mg/liter DO started and finished spawning at earlier dates than those at the higher oxygen concentrations; fish at saturation started and finished spawning at later dates than those at the reduced concentrations. The number of embryos from a single spawning ranged from 14,600 to 155,300. Number of spawnings, viability of embryos, hatching success, and survival through swim-up were similar between control fish and those exposed to reduced oxygen concentrations.

The effects of reduced dissolved oxygen (DO) concentrations on the early life history of several centrarchids have been reported (Carlson and Siefert 1974; Siefert et al. 1974; Dudley and Eipper 1975), but little information is available concerning the effects on centrarchid spawning success. Peterka and Kent (1976) measured DO as low as 2.4 mg/liter in pumpkinseed (*Lepomis gibbosus*) nests that contained viable embryos. Largemouth bass (*Micropterus salmoides*) spawned successfully in laboratory tanks at 3.1 and 4.5 mg/liter (Siefert, unpublished data[1]). We know of no other investigation where centrarchids have been exposed to known reduced DO concentrations during the spawning period. Fathead minnows (*Pimephales promelas*) did not spawn at 1 mg/liter DO, and at 2 mg/liter they produced fewer embryos than at concentrations of 3 mg/liter and higher (Brungs 1971). This paper describes the spawning behavior and early development of black crappies (*Pomoxis nigromaculatus*) maintained continuously at DO concentrations as low as 2.5 mg/liter and as high as air saturation.

METHODS

Mature black crappies were netted from the Mississippi River near Genoa, Wisconsin, and delivered to the laboratory in August 1974. The fish were transported at 19 C; the laboratory holding temperature was steadily decreased to 8 C by 15 November and 4 C by 25 January. After 78 days at 4 C a simulated natural spring rise in temperature, based on data from Lake Mendota, Wisconsin (Reid 1961), was initiated. On 24 June, 20 C was reached, and this temperature was held until test end. A simulated natural light cycle (Duluth, Minnesota) was regulated, as described by Drummond and Dawson (1970), for the entire holding and testing period. Average daytime illumination at the water's surface was 20 lumens.

Most fish had a fungal infection on arrival, which was cleared after 2 weeks of treatments with formalin (1-h static, 170 ppm), Roccal[2,3] (1-h static, 20 ppm), and Terramycin[4] (1-h static, 10 ppm) (no more than one treatment with any compound each day). Thereafter, fish were given a prophylactic treatment biweekly alternating 1-h static formalin (170 ppm) and Roccal (20 ppm). Treatments were ended in April before the spawning season.

On 30 April the fish were weighed and measured, and a determination of sex was attempted by using secondary sexual characteristics. Five fish averaging 243 mm in length and 270 g in weight were placed in each of ten 1.2-m diameter (734-liter) fi-

[1] Environmental Research Laboratory-Duluth, Duluth, Minnesota 55804.

[2] The U.S. Environmental Protection Agency neither recommends nor endorses any commercial product; trade names are used only for identification.

[3] Sterling Drug Inc., Montvale, New Jersey 07645.

[4] Charles Pfizer & Co., Inc., New York, New York 10017.

berglass tanks. At the same time two artificial nests, each consisting of a plastic dishpan containing a nylon mesh mat (Conservation Web[3]) on the bottom, were placed in each 62-cm-deep circular tank. About 20 small stones were placed on top of every web to act as indicators of courtship activity if moved, and to lend some semblance of a natural substrate.

On 1 May and thereafter the fish were exposed to five duplicate DO concentrations consisting of a control near air saturation, and reduced concentrations near or at 6.5, 5.0, 3.5, and 2.5 mg/liter. Degassed water from a vacuum degassing system (Mount 1964) was mixed with saturated water in glass mixing chambers to produce the prescribed DO concentrations. The water was then pumped by in-line water pumps through stainless steel coils in a water bath to reach the desired temperature and was delivered into the test tanks through flow meters at about 1.38 liters/min. Water to the control tanks was delivered down a screen cylinder to eliminate supersaturation. Tanks were assigned the test DO concentrations randomly.

Characteristics of the untreated Lake Superior test water have been described by Siefert et al. (1974). Range in pH was 7.2–7.5. Temperatures were measured daily in all tanks. Dissolved oxygen was measured daily in at least one of each of the duplicate tanks by the unmodified Winkler method.

The crappies were offered (to satiation) fathead minnows three times a week; they fed well at all DO concentrations throughout the test. Fecal material was siphoned daily, and tanks were cleaned and partially drained weekly except during the spawning period. The test was ended on 3 July, 7 days after the final spawning and after several of the males had abandoned their territories. Judging by external and internal examination at this time, the fish were in excellent condition.

Embryos used to test for viability, hatching success, and swim-up were transferred with a pipet from the nests to 100-ml glass vials, the bottoms of which had been replaced with fine-mesh stainless steel screen. For viability studies, which were performed on all spawnings, 100 embryos were placed in each of three vials. These vials were suspended in a water bath with a DO concentration near air saturation and at or near the optimum incubation temperature. The incubation was continued until the viable embryos formed a neural keel. For hatching and swim-up tests, which were performed on most of the spawnings, 100 embryos were placed in each of two vials, and suspended in the tank in which they had been spawned. These embryos were checked frequently until hatching was complete. Dead embryos and larvae were removed and observations were continued until all surviving larvae were free-swimming. In each tank the DO concentration in the vials varied little or not at all from that in the rest of the tank.

After the embryos needed for the above tests were removed, the remainder were transferred from the nest to a graduated cylinder for a volumetric measurement. Three samples of 1–3 ml were counted, and the total number of embryos spawned was calculated.

RESULTS AND DISCUSSION

Reduced dissolved oxygen (DO) concentrations over the range tested had little or no discernible effect on the occurrence of successful spawning or on the number of embryos, viability, hatching success, and survival through the swim-up stage (Table 1). However, the DO concentration did appear to affect spawning behavior since the fish at 2.5 mg/liter exhibited territorial behavior and started and finished spawning at earlier dates, and therefore at lower temperatures, than the fish at higher DO concentrations. Fish at saturation were among the last to start and finish spawning, and this occurred at the highest spawning temperatures.

Prior to spawning, male fish set up territories over individual nests, and the same male guarded the same nest through the spawning period. One test tank contained only one male and therefore had one vacant nest. Observations of several spawnings revealed that females on occasion would spawn with both nesting males. Also, two

[3] Minnesota Mining and Manufacturing Company, St. Paul, Minnesota 55101.

TABLE 1.—*Number of spawnings, viability of embryos, hatching success, and swim-up of offspring of black crappie at a natural photoperiod and temperature regime and at the dissolved oxygen concentrations indicated.*

Dissolved oxygen concentration (mg/liter)			Sex ratio[a] Male: Female	Number of spawnings	Range of dates of spawnings	Range of spawning temperatures (C)	Mean number of embryos per spawning[b] 10^3
Nominal	Mean ± standard deviation	Range					
Saturation	92.7[c] ± 4.2[c]	82–98[c]	3:2	8	6/15–6/26	18–20	36.0
Saturation	91.8[c] ± 4.4[c]	83–99[c]	2:3	1	6/23	19	42.1
6.5	6.6 ± 0.3	6.1–7.4	1:4	3	6/8–6/10	16–17	89.2
6.5	6.4 ± 0.3	5.5–6.9	2:3	4	6/6–6/24	16–20	71.1
5.0	5.1 ± 0.3	4.5–5.9	2:3	8	6/10–6/23	17–19	64.2
5.0	5.1 ± 0.2	4.6–5.8	3:1	2	6/18	18	43.3
3.5	3.7 ± 0.4	3.3–5.0	2:2	4	6/15–6/20	18–19	47.4
3.5	3.5 ± 0.2	3.1–4.1	3:2	2	6/7–6/16	16–18	97.1
2.5	2.5 ± 0.3	1.9–3.0	3:2	4	6/3–6/12	15–17	64.6
2.5	2.7 ± 0.3	2.2–3.4	2:3	3	5/26–6/17	13–18	106.3

Dissolved oxygen concentration (mg/liter)	Range of embryos per spawning 10^3	Total embryos spawned[b] 10^3	Mean percentage viability per spawning and range of percentage	Mean percentage hatching success per spawning, range of percentage, and (in parentheses) number tested	Mean percentage swim-up(s) per spawning, range of percentage, and (in parentheses) number tested
Nominal					
Saturation	14.6–66.8	288.2	94.6, 87–99	93.7, 85–99 (7)	91.8, 78–100 (4)
Saturation	42.1	42.1	97.0, 97	89.0, 89 (1)	97.0, 97 (1)
6.5	59.8–112.3	267.5	96.7, 94–99	97.0, 97 (2)	
6.5	44.4–144.7	308.6	84.8, 60–99	92.7, 88–99 (3)	99.3, 98–100 (3)
5.0	29.0–80.5	513.4	94.4, 85–99	81.4, 44–98 (7)	100.0, 100 (5)
5.0	25.7–60.8	86.5	96.0, 95–97	66.0, 35–97 (2)	99.5, 99–100 (2)
3.5	25.5–58.5	189.7	95.3, 91–98	75.8, 32–95 (4)	99.7, 99–100 (3)
3.5	79.0–115.3	194.3	95.5, 94–97	96.0, 94–98 (2)	96.0, 96 (1)
2.5	41.2–94.0	278.6	97.0, 95–98	92.7, 86–98 (3)	91.0, 91 (1)
2.5	80.1–155.3	318.9	97.7, 96–99	67.5, 38–97 (2)	97.0, 97 (2)

[a] Mature fish only; one immature fish in a 5.0 and a 3.5 mg/liter tank.
[b] To the nearest hundred.
[c] Percent air saturation. Dissolved oxygen concentrations in the controls were adjusted with the rising water temperatures to allow an oxygen tension at or near air saturation. Range was 7.7–11.2 mg/liter.

females were observed spawning with the same male. For these reasons the differences in number of embryos per spawning may not be a valid representation of the reproductive capacity of an individual female at any particular DO concentration.

Obviously, the number of spawnings in each tank affected the number of embryos produced in that tank. The largest variations in number of spawnings between duplicate tanks occurred in the controls and at 5.0 mg/liter DO. We do not know why only one spawning occurred in one of the control tanks. All tanks but one at 6.5 mg/liter DO had two nest-guarding males; all but one at 5.0 mg/liter DO had at least two mature females. An unbalanced sex ratio may have been the reason for the relatively small numbers of spawnings in those two tanks. However, three males in this test fertilized four spawnings each, and one male fertilized five. Also, there were eight spawnings in one control tank containing only two females.

Although there was good spawning success at all reduced DO concentrations, the earlier spawnings at the lower DO concentrations could affect the survival of offspring in a natural environment. However, the ecological significance, if any, of these earlier spawnings is unknown.

ACKNOWLEDGMENTS

We thank Mr. J. C. Blocher for assisting in the maintenance of the test, Dr. W. A. Spoor for technical and editorial guidance,

and the Genoa National Fish Hatchery Personnel for providing the adult fish.

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